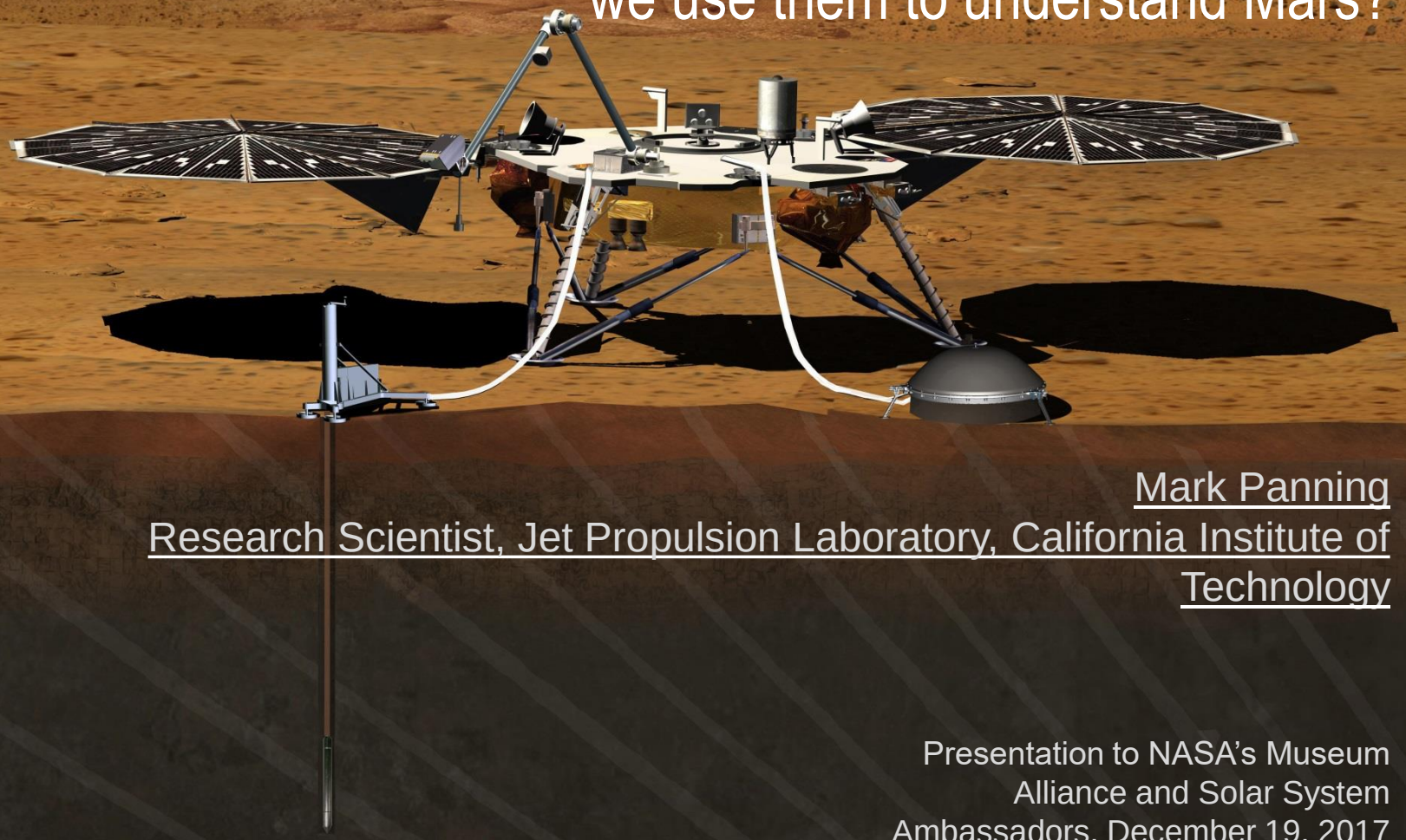
InSight

Marsquakes: How do we detect them, and how do we use them to understand Mars?



Mark Panning
Research Scientist, Jet Propulsion Laboratory, California Institute of Technology

Presentation to NASA's Museum Alliance and Solar System Ambassadors, December 19, 2017

A more basic question: What are earthquakes?

Obviously, the biggest reason most people think about earthquakes is in the context of natural hazards, but seismologists use them to learn about the physics of what cause them, and what the Earth looks like between where the quakes happen and where we observe them

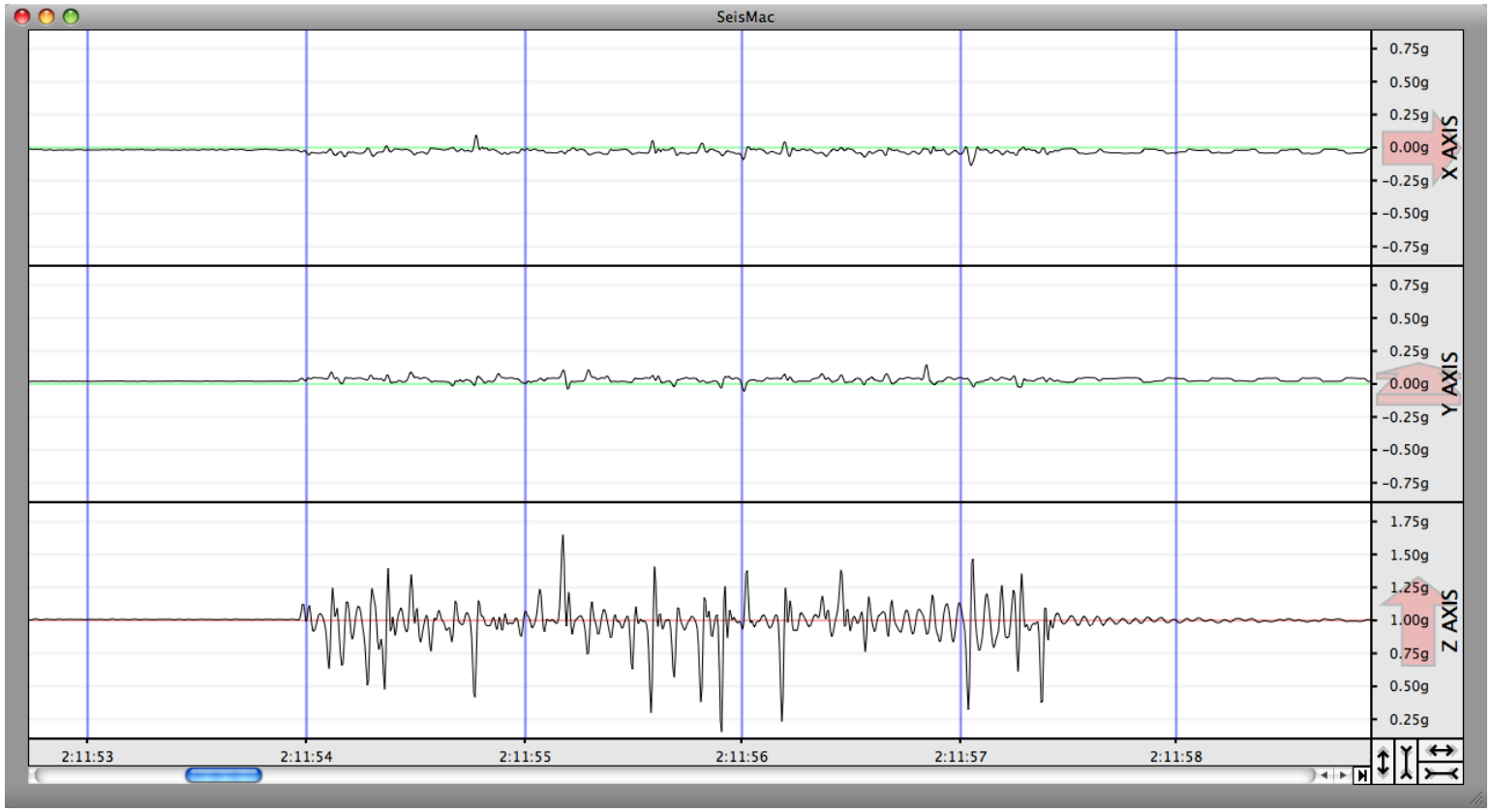
Earthquakes (and marsquakes) happen on faults

Quakes make waves

Marsquake visualization from Martin van Driel, ETH Zürich

Seismometers measure waves

Example output from SeisMac, which makes seismograms from the seismometer inside a laptop (most laptops and phones have accelerometers, compared with a seismogram from an earthquake)



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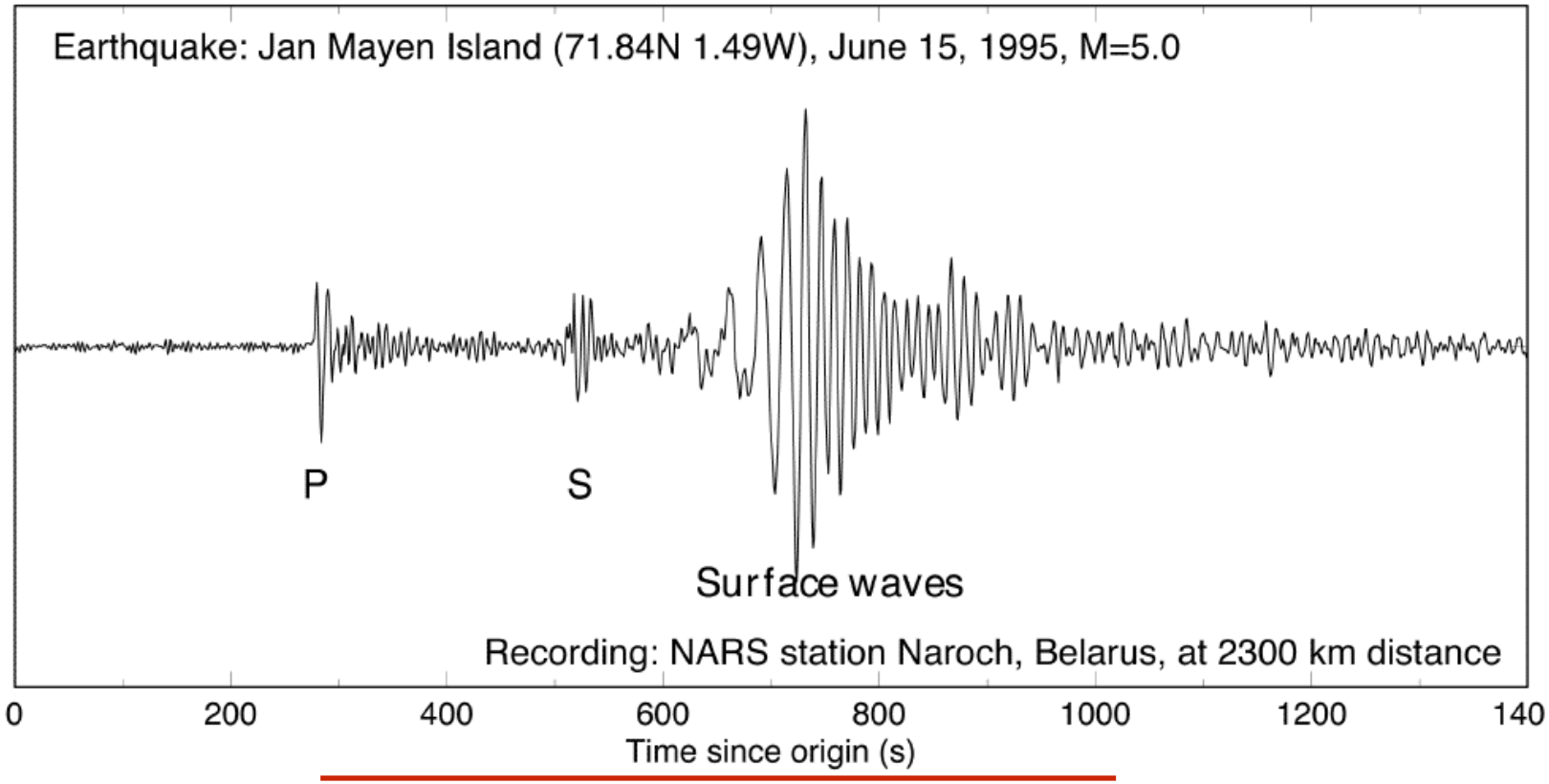
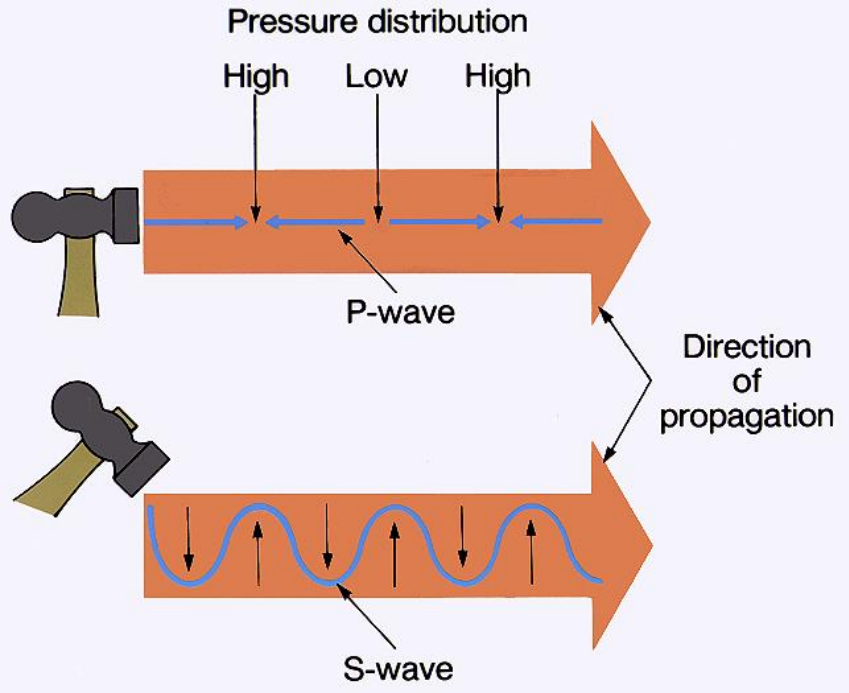


EQ faulting: ~1 second
Seismogram: ~12 minutes

A seismometer for Mars

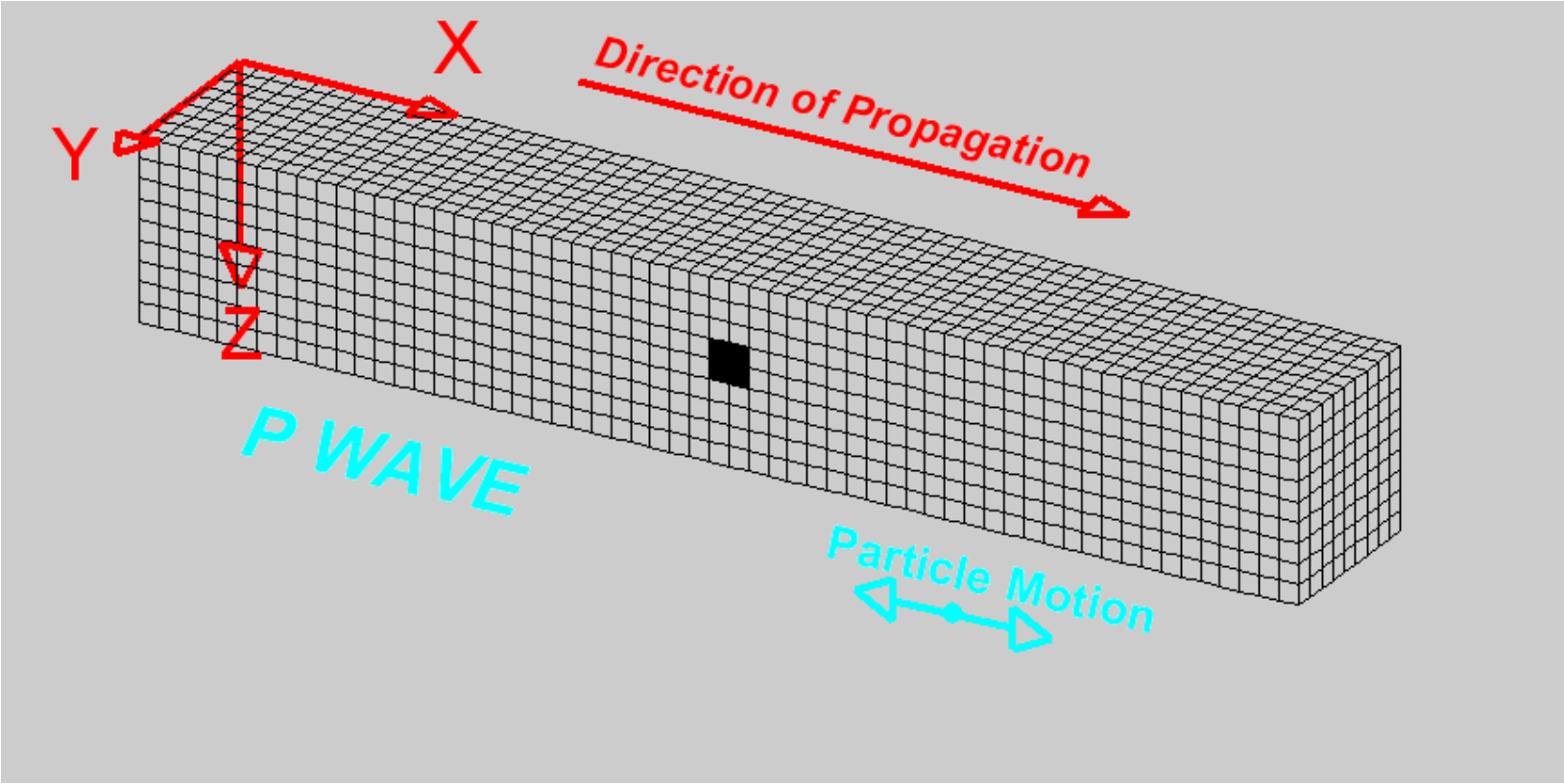
Wherever they are, quakes make the same kind of waves

Body waves go through the interior (or body) of the planet, and can be divided into two types:



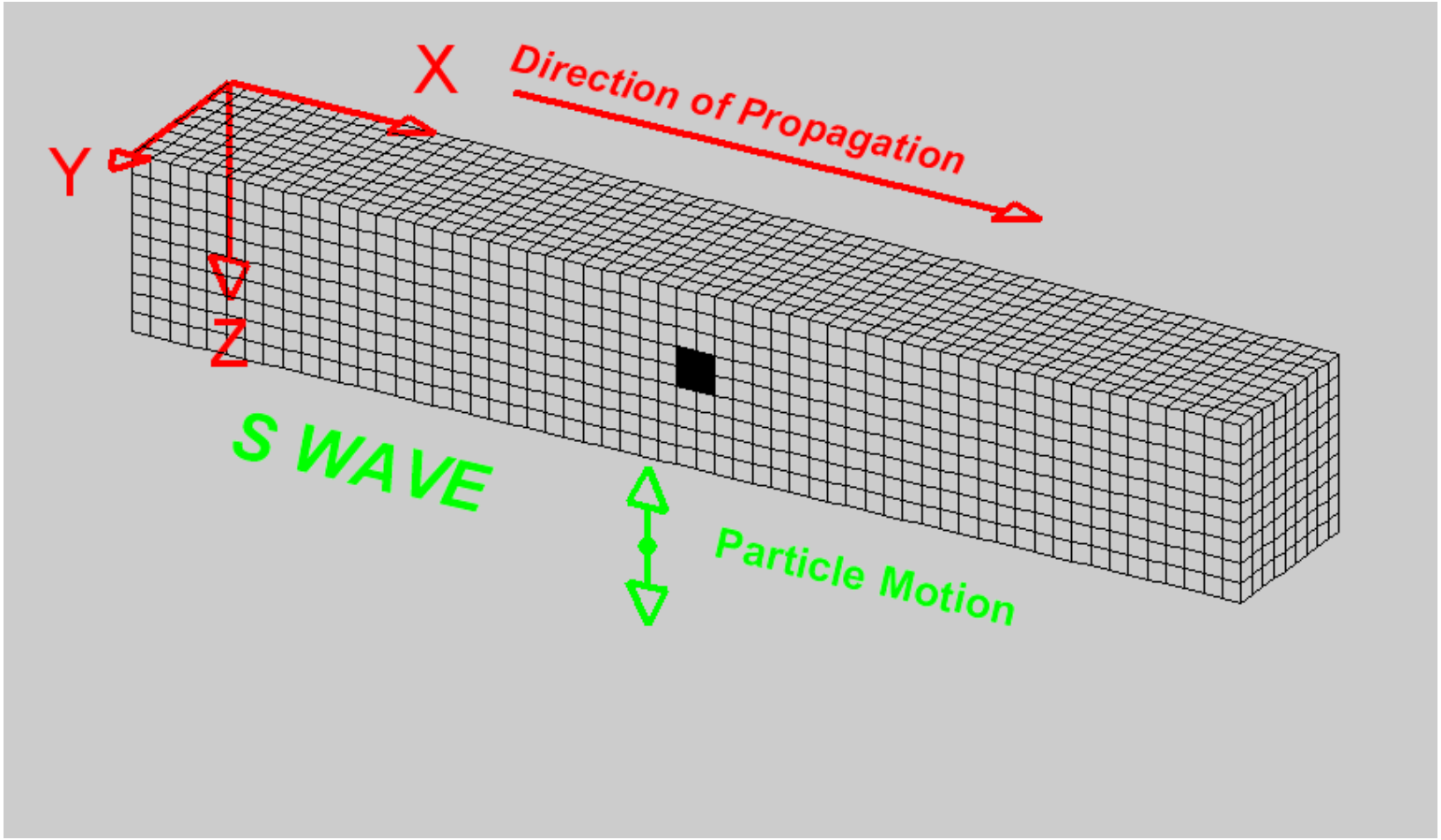
Surface waves travel around stuck to the top of the planet

P waves



http://web.ics.purdue.edu/~braile/edumod/waves/WaveDemo.htm

S waves



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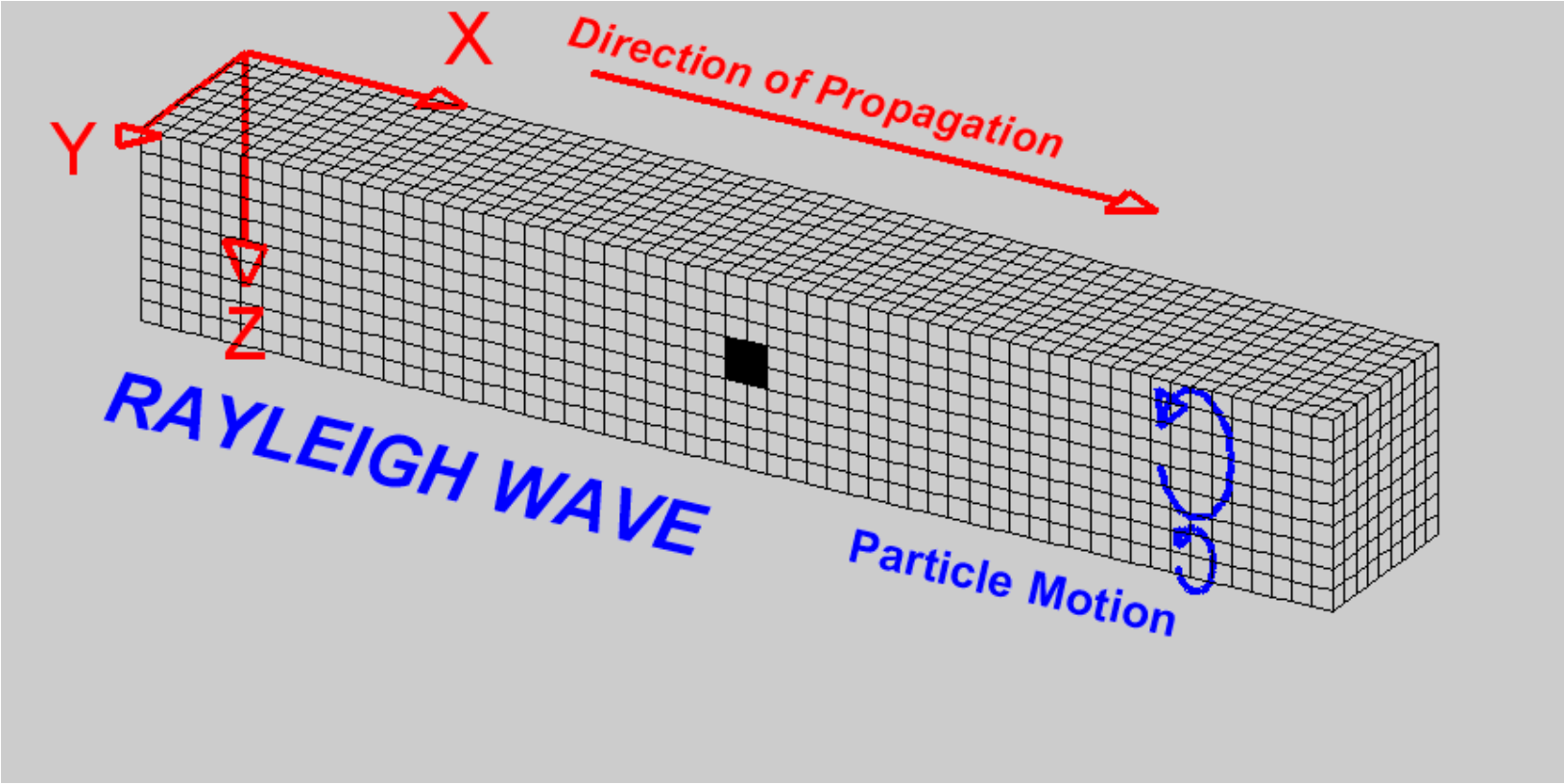
Rayleigh waves



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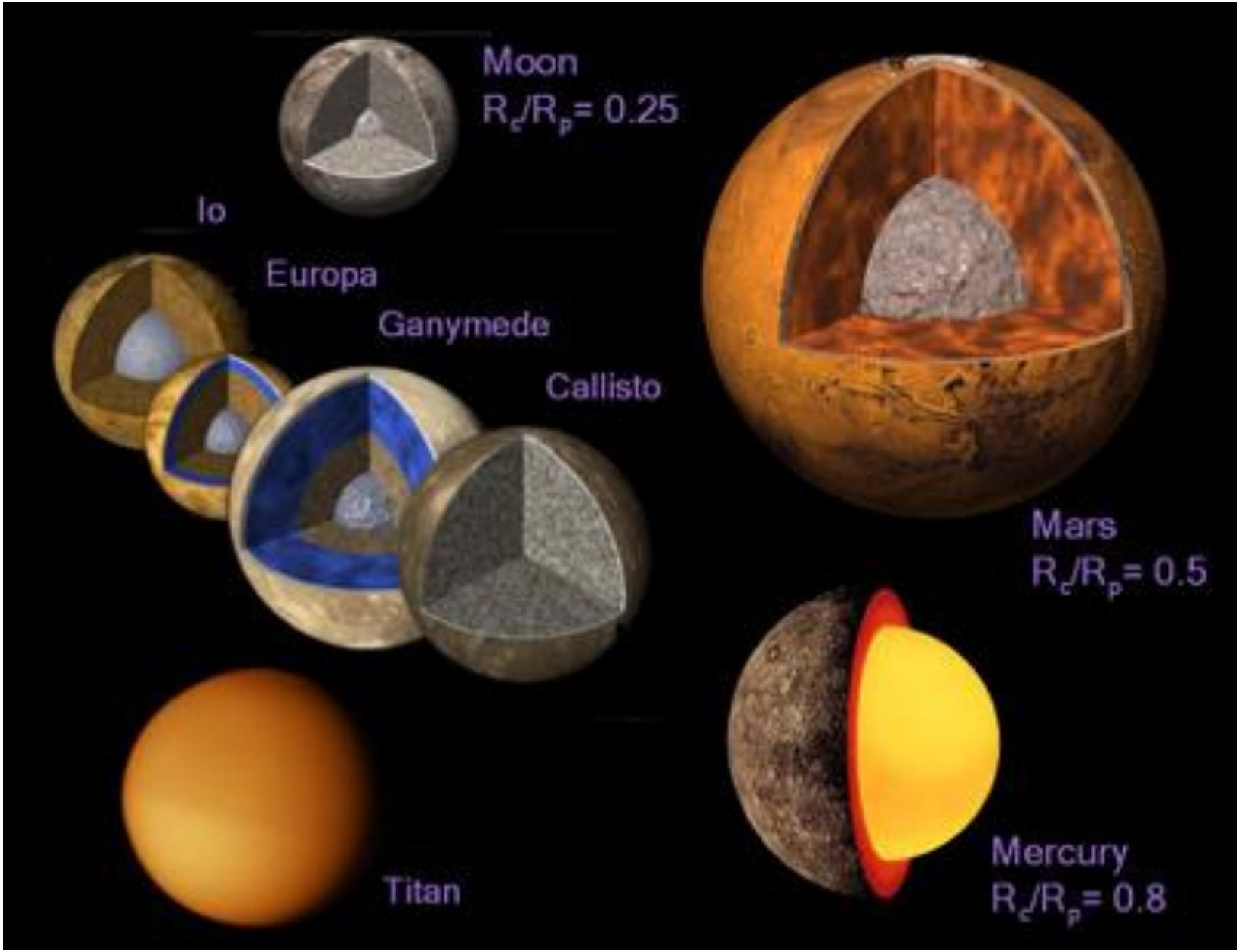
Why planetary seismology?

- Planetary missions tend to focus on surface observations, which do not tell us directly about what's inside planets
- Most of our detailed knowledge of the interior structure of the Earth comes from seismology
- Most of what we know about planetary interiors comes from gravity measurements plus educated guesses about chemistry

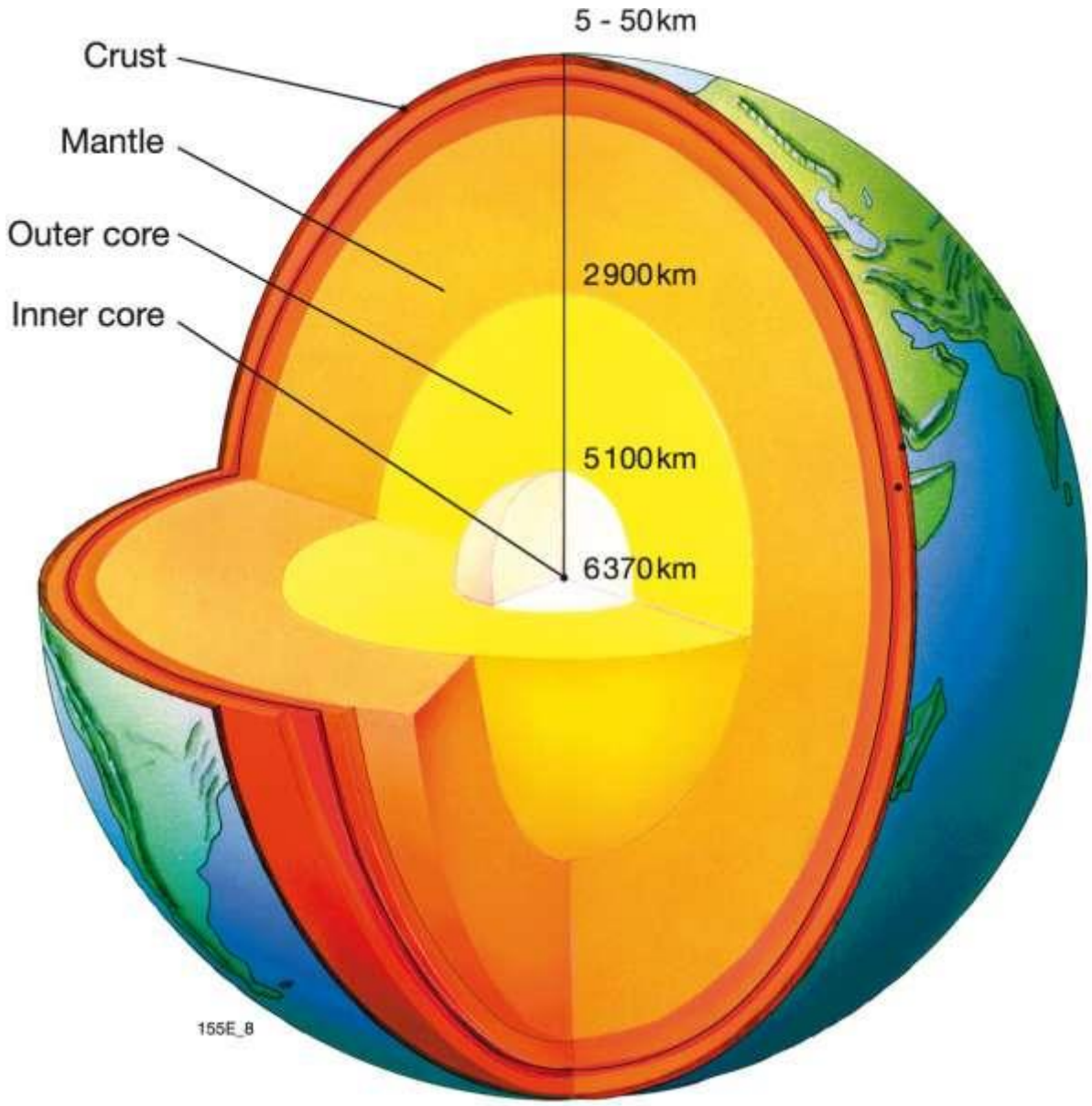
Comparing Earth, Moon, and Mars on the same scale

Earth Mars Moon

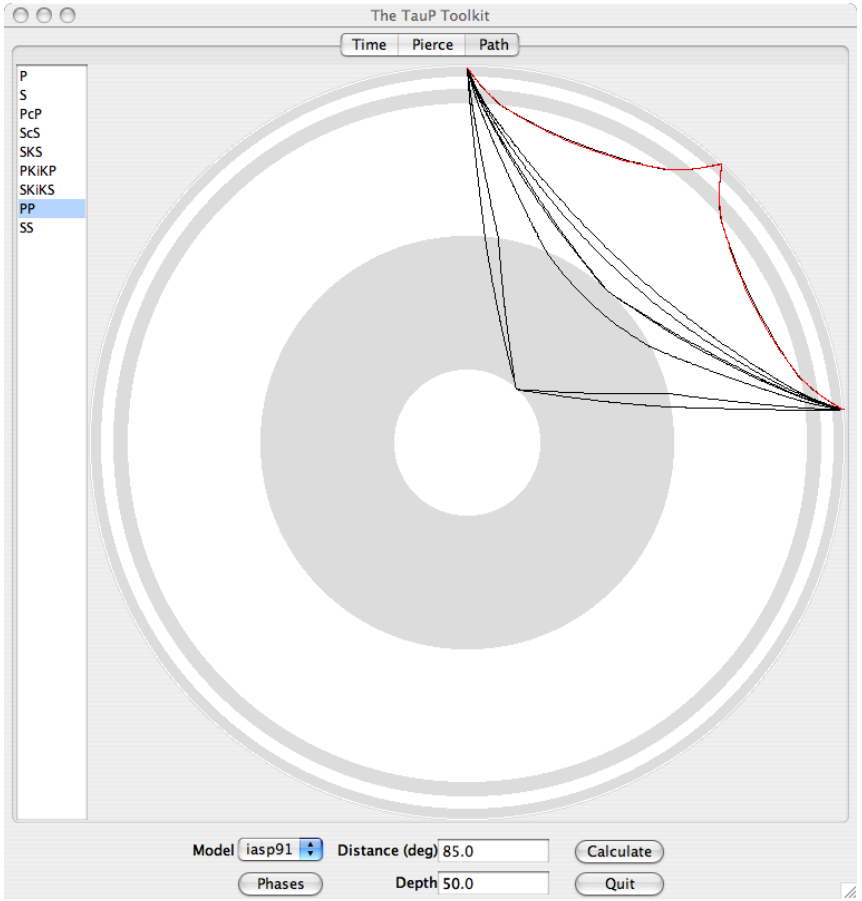
Planetary interiors, or at least our best guesses

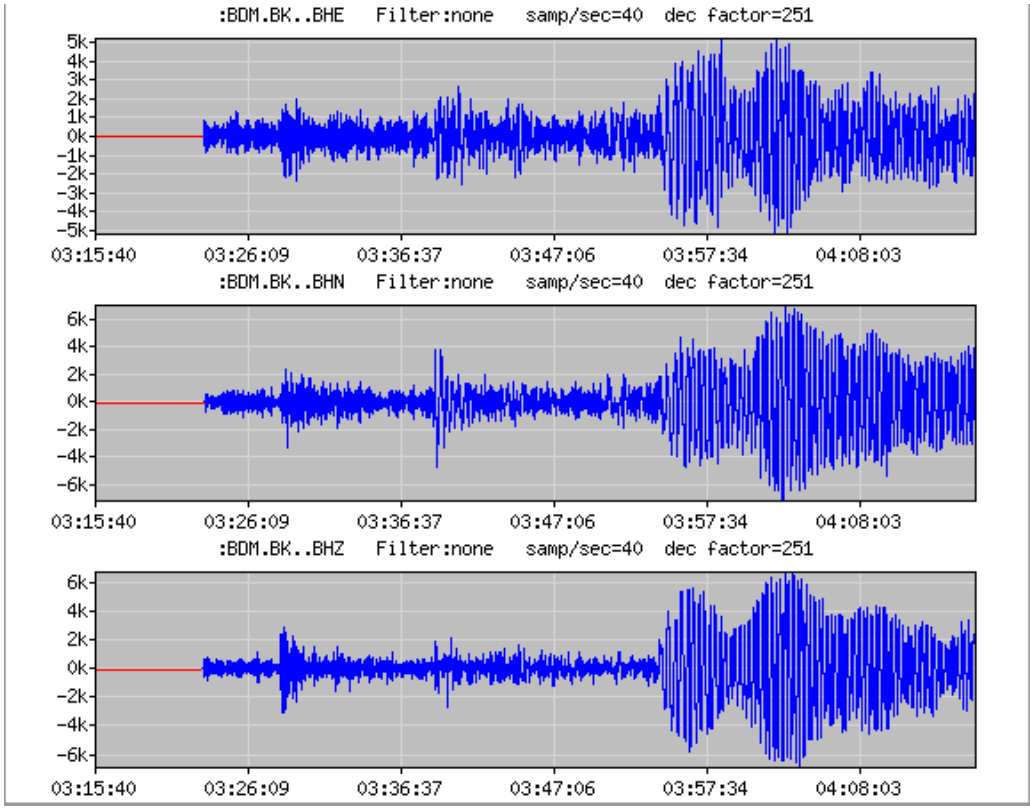


For the Earth, we know the inside structure very well



Seismology teaches us planetary structure





History of planetary seismology

- The “good”: 5 seismometers were placed on Earth’s moon and recorded data (Apollo 11, 12, 14, 15, and 16 missions 1969-1972)
- Data recorded until 1977

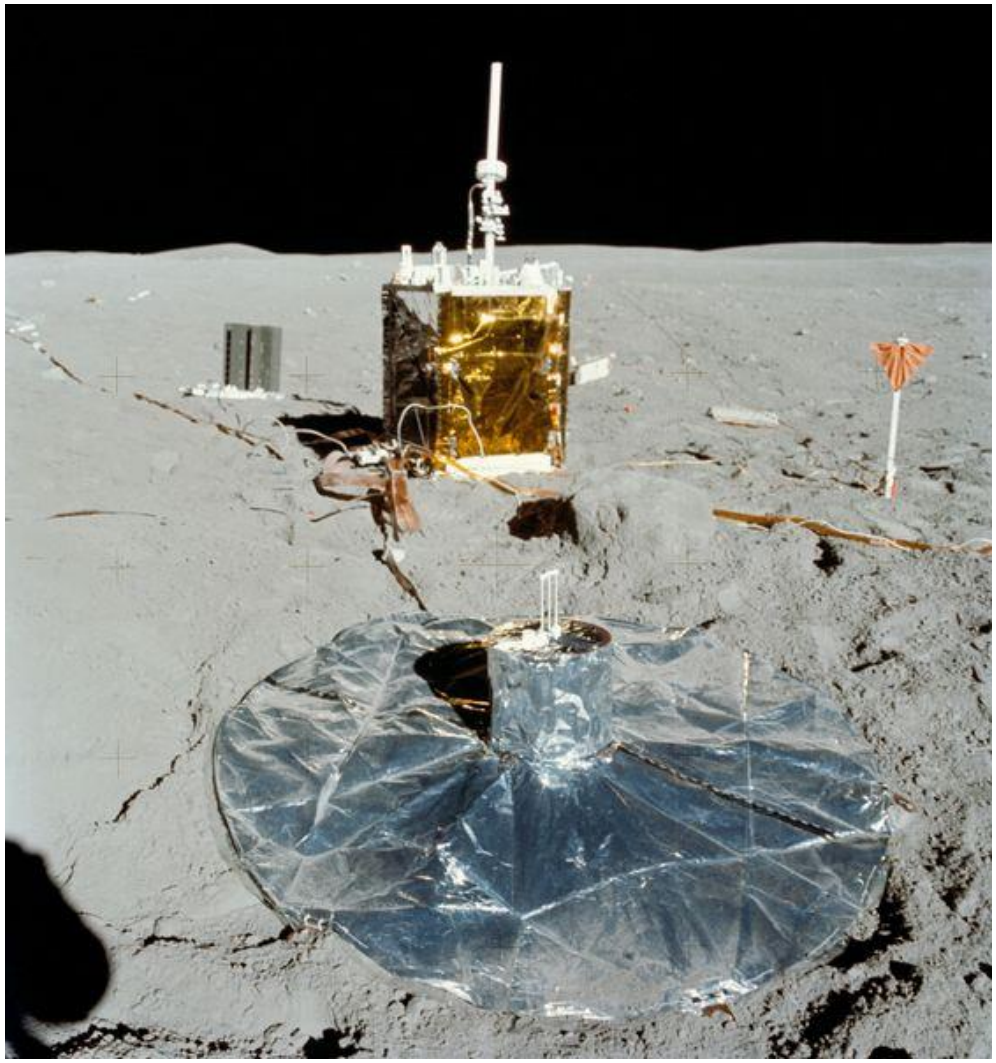


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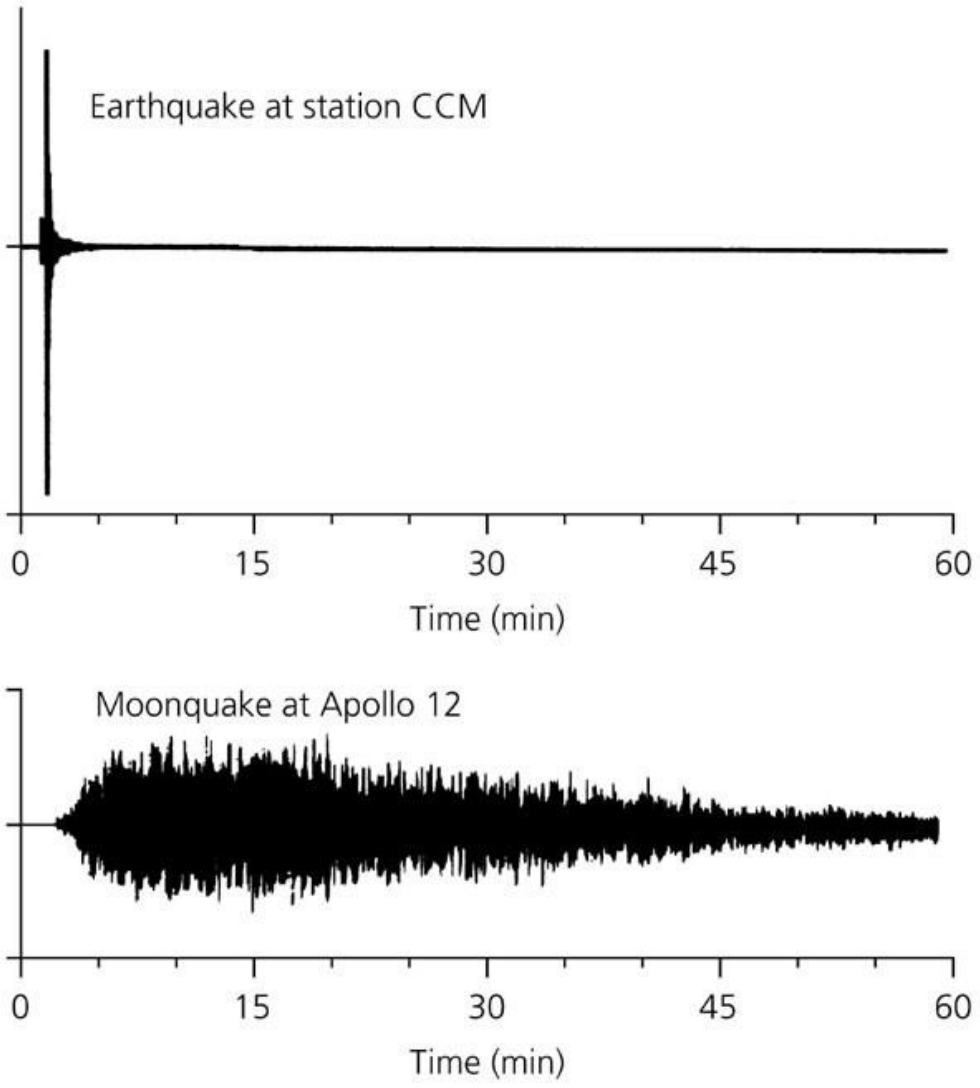
Figure 3.7-10: Comparison of seismograms on the earth and moon.



History of planetary seismology

- The “bad”:
- Viking landers included seismometers

1 didn’t “uncage” – no data

The other primarily recorded the rocking of the lander due to wind

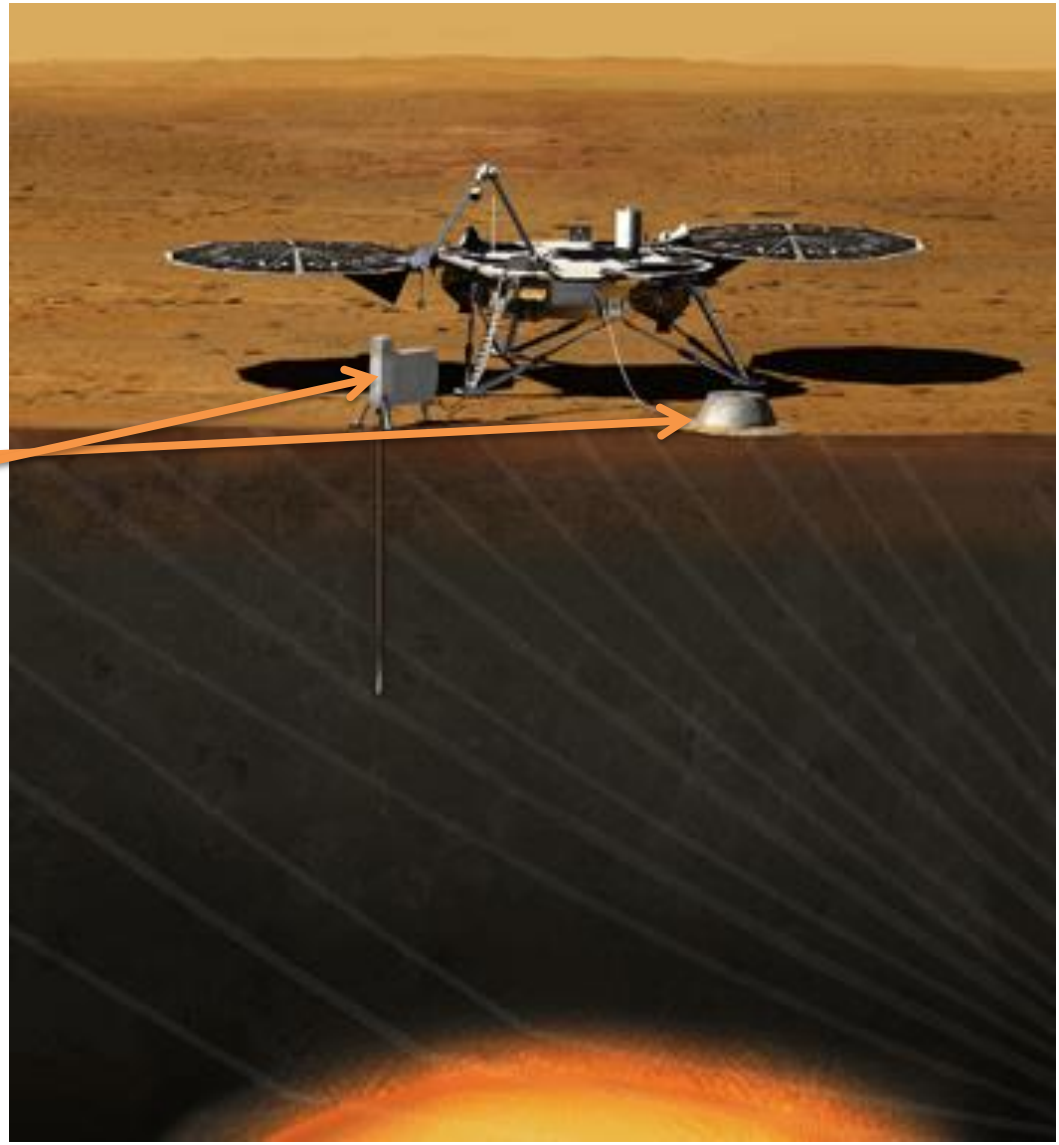
History of planetary seismology

- The “ugly”: At least 10 other seismometers have been included in launched missions that failed for a variety of reasons

Mars 96 – failed due to launch vehicle stage failure – never escaped Earth orbit

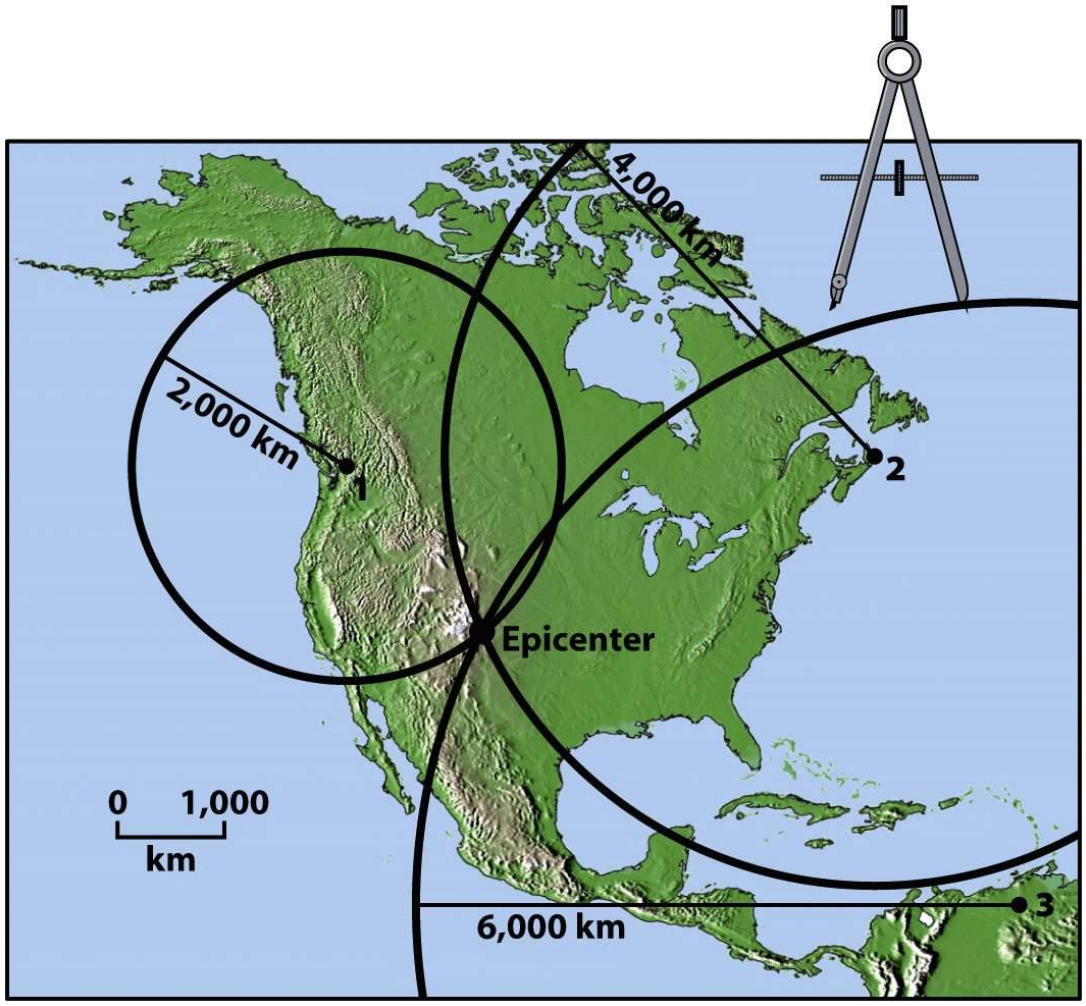
InSight

- Launches May 5, 2018 (6 months travel time)
- Instruments on board
  - SEIS
  - HP^3
  - RISE
  - Cameras
- Should return data for ~1 martian year (about 2 Earth years)



Seismic networks are pretty cool

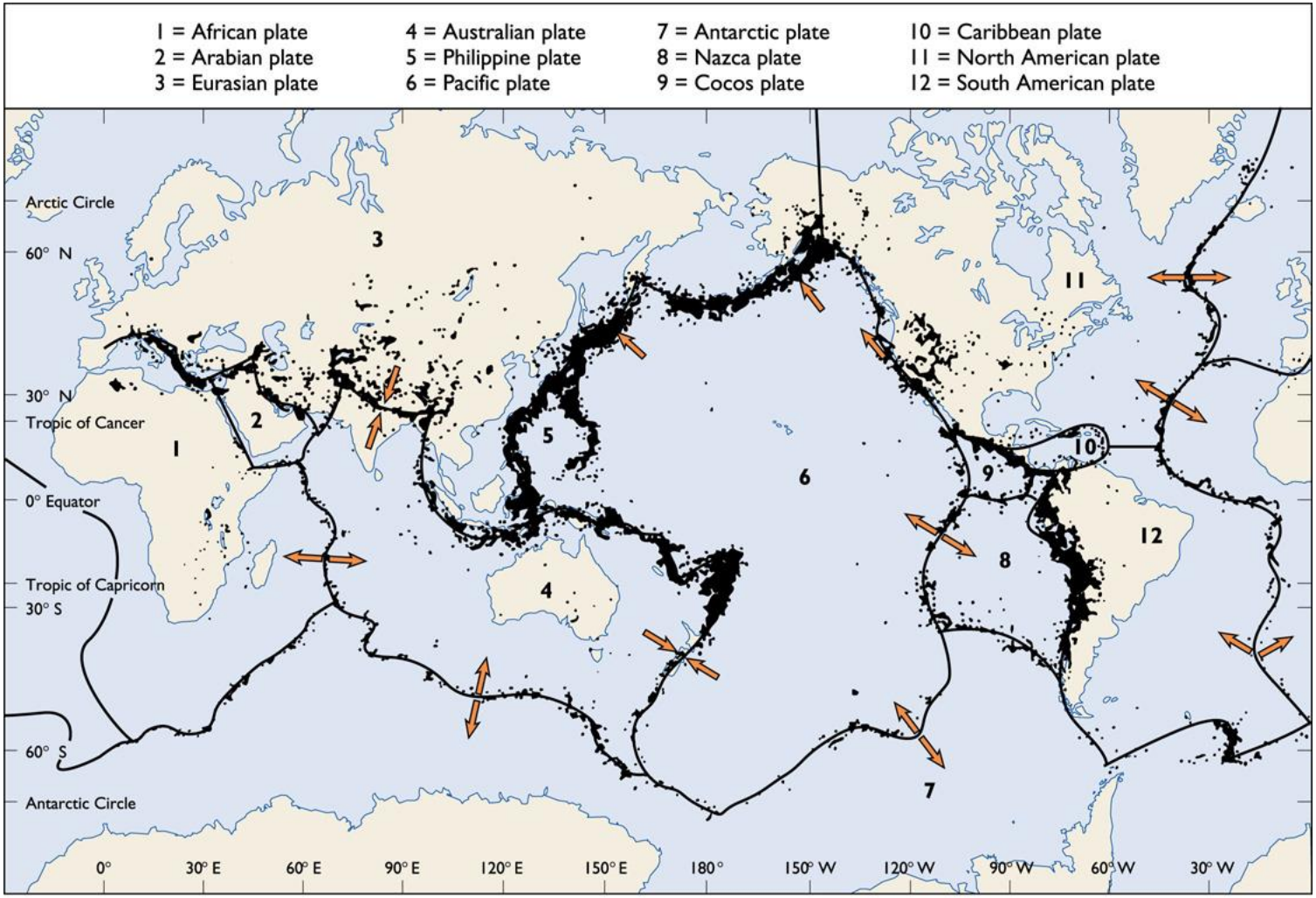
- Modern seismology relies on networks
  - Accurate locations and origin times
  - Array seismology techniques



What are we going to do with only one station on Mars?

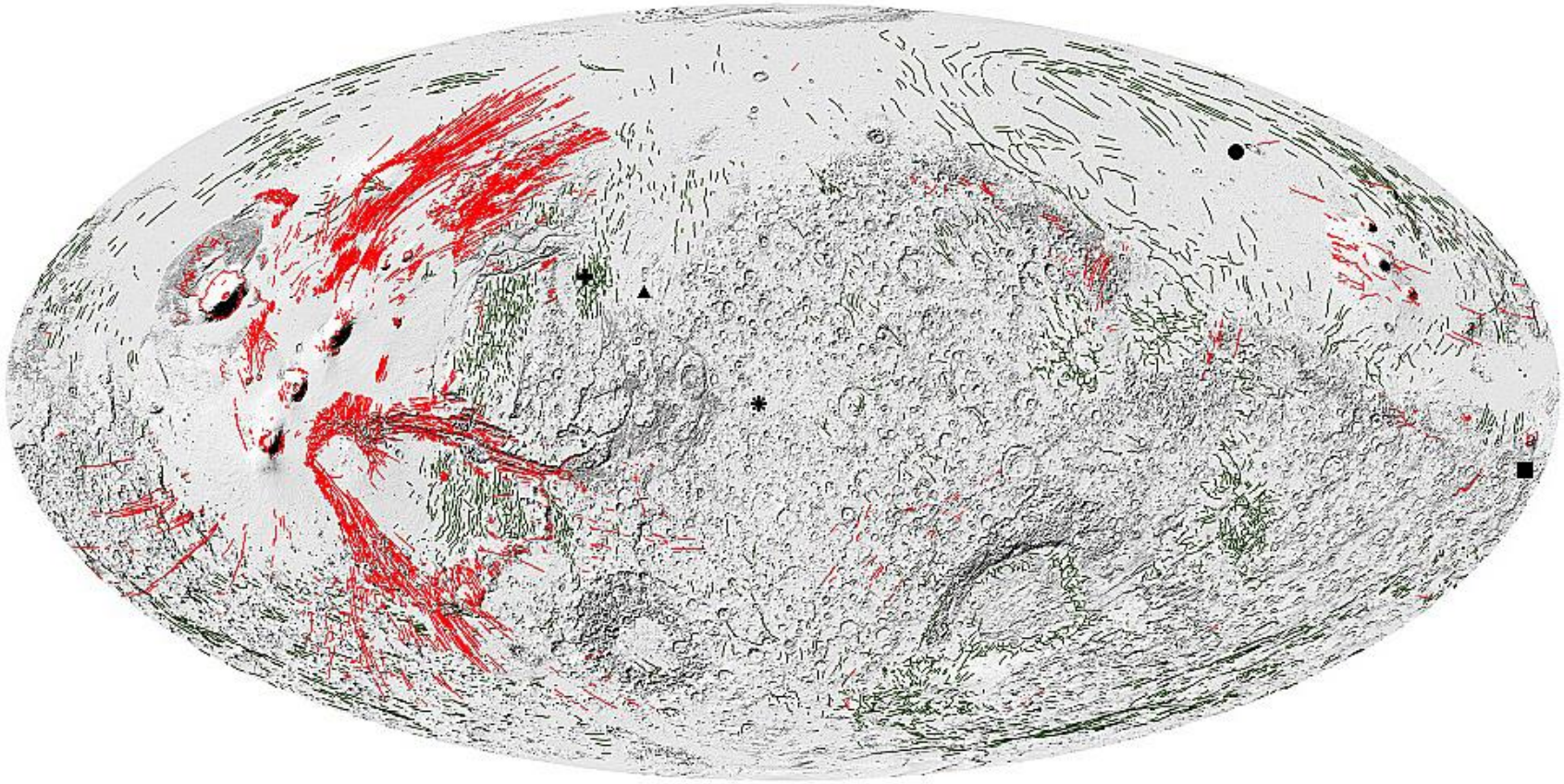
- Having a network on Mars would be wonderful (and it's been proposed many times)
- Having one station allows for an infinite relative increase in our seismic data, though!
- Two options for how to proceed if we want to model the interior seismic structure of Mars
  - Techniques that don't require location information
  - Single station location techniques

Where do we see earthquakes?



Earthquakes, shown as black dots, occur at boundaries of large plates

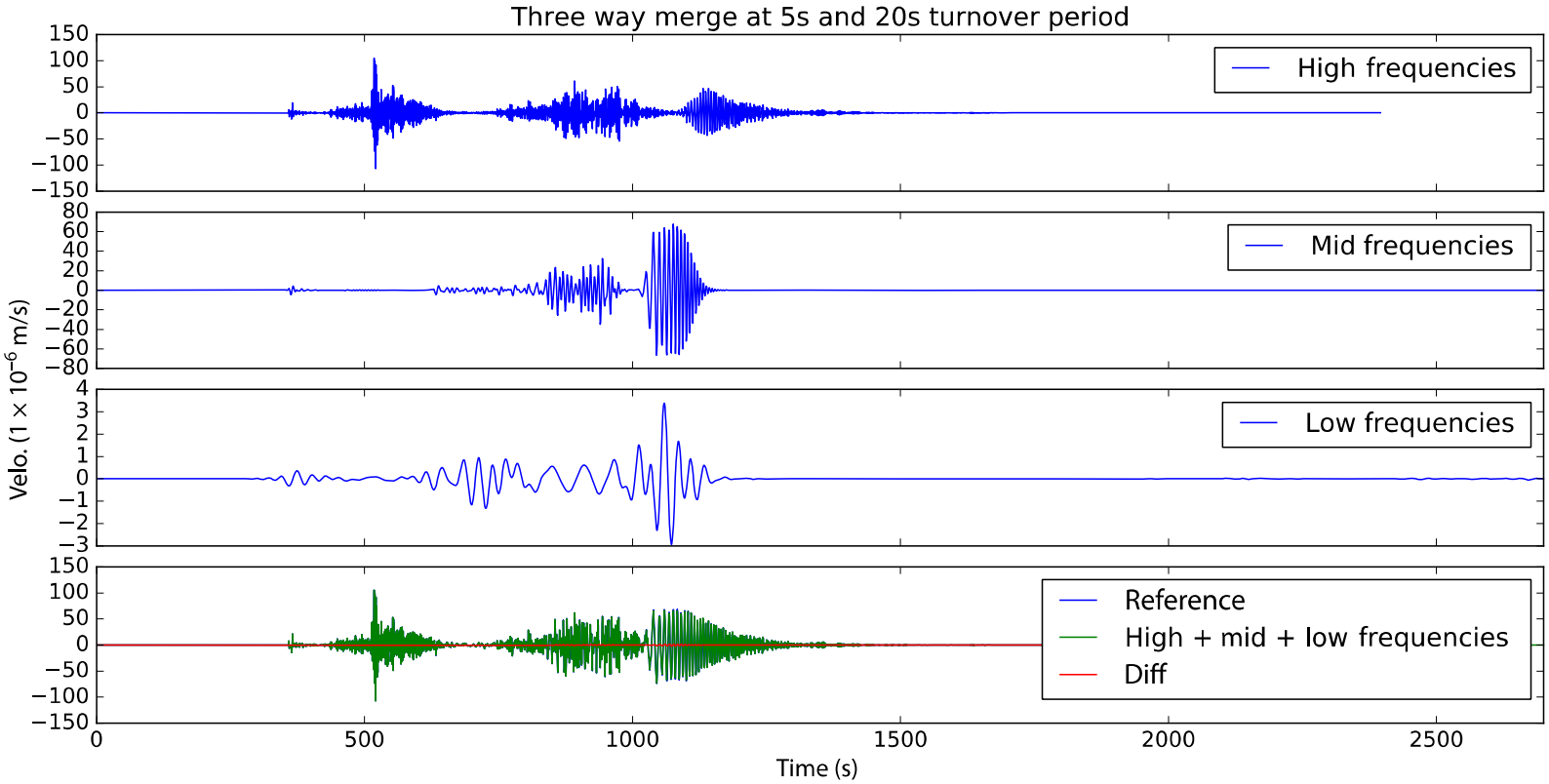
Will we see Marsquakes?



Fault map from Martin Knapmeyer, showing faults observed from orbital images in red and green (no plate tectonics on Mars, but plenty of faults)

What will seismograms look like on Mars?

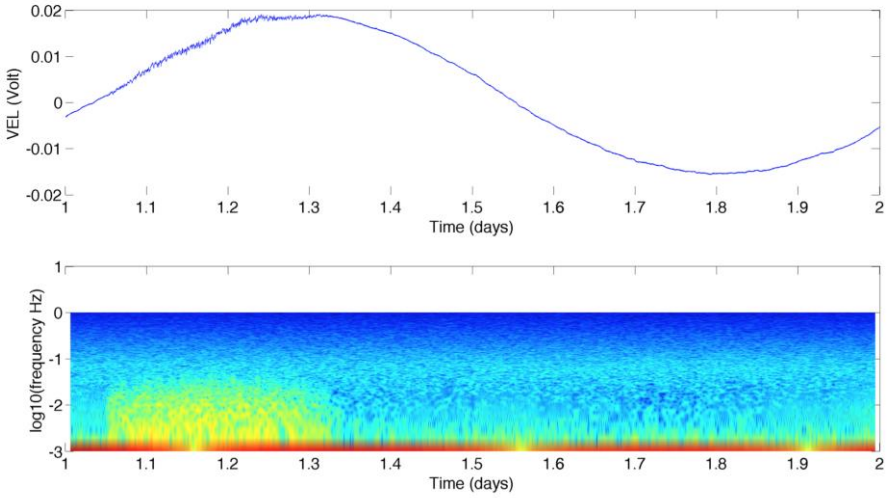
- ✓ We can use computational techniques to simulate seismograms through Mars



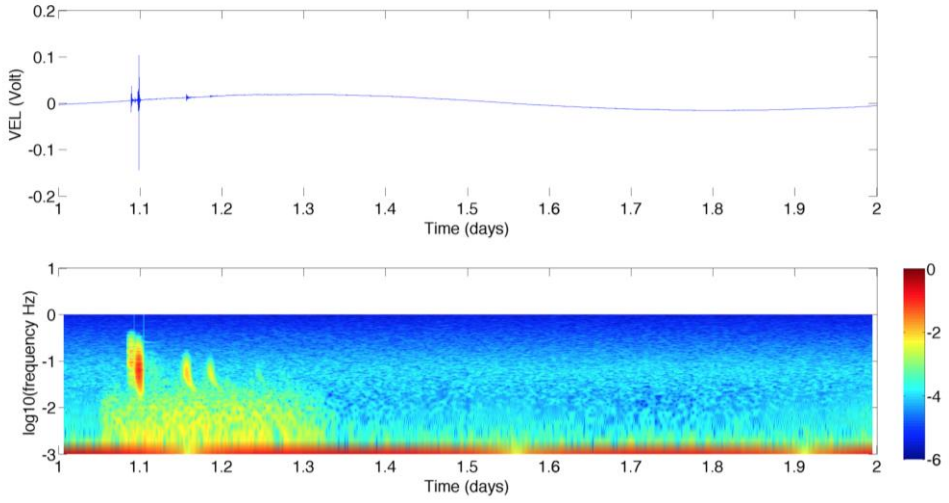
What will seismograms look like on Mars?

- ✓ We can add simulated noise from atmospheric, temperature, and even tidal variations

Noise

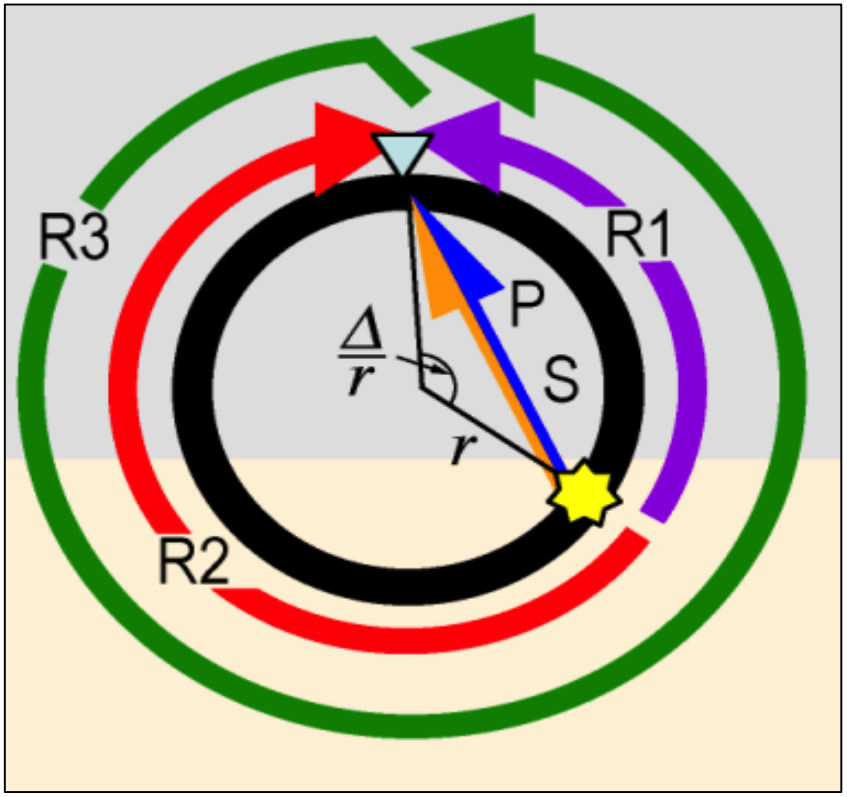


Marsquake + noise

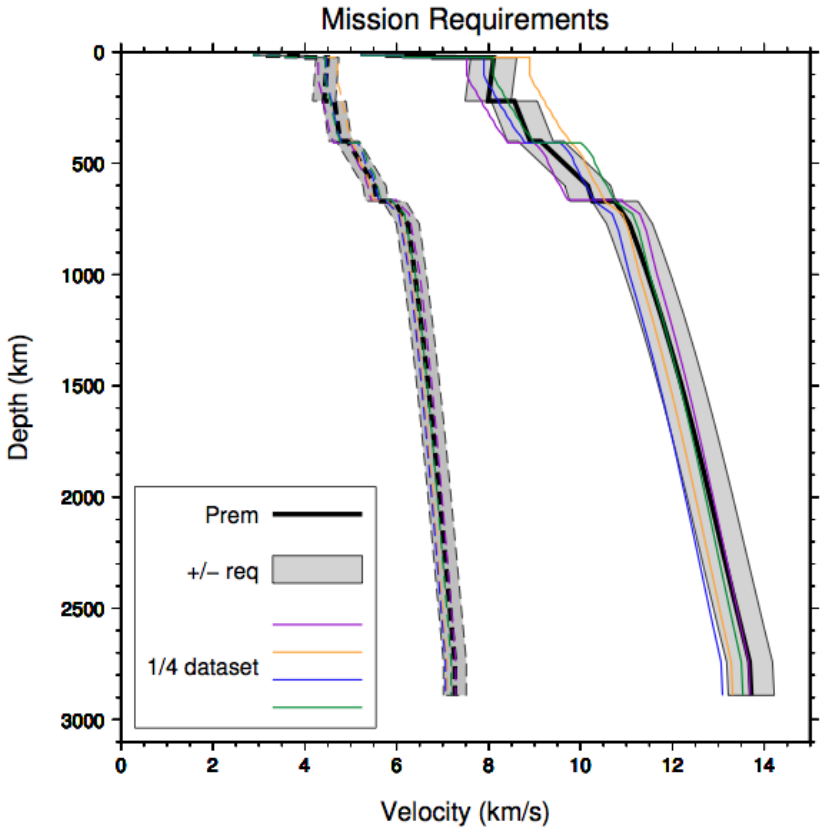


Single station location

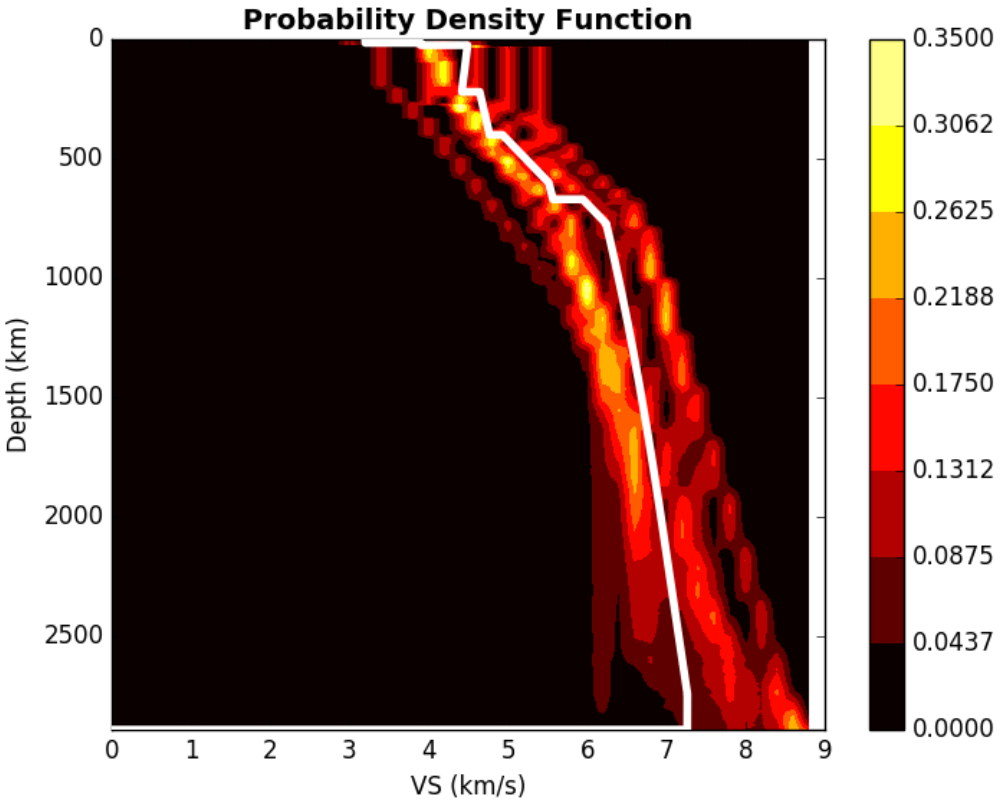
- We estimate location using the timing of 3 orbits of surface waves (called R1, R2, and R3). There are 3 unknowns: Δ, the distance, t_0, the origin time, and U, the surface wave group velocity.
  - U=2π/(R3-R1)
  - Δ=π-U(R2-R1)/2
  - t0=R1-Δ/U



Testing with Earth data from a single station



With 7 “big” events



With only 5 smaller events

Summary

- To know about the inside of a planet, nothing's better than seismology
- We're going to land a seismic station on Mars next year
- We should see marsquakes, and we should be able to use them to figure out the internal details of Mars